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DIFFERENTIAL-DRAG ALGORITHMS FOR SATELLITE CLUSTER FLIGHT IN THE SAMSON MISSION

Abstract

The idea of differential drag (DD) as a means for fuelless satellite cluster keeping emerged in the mid-Eighties, when the feasibility of DD-based control was proven assuming linearized relative dynamics for two satellites. A real mission controlled by a DD-based method will be a breakthrough in the field of long-term cluster flight, since it potentially makes the thrusters and fuel unnecessary.

The present work develops a new DD-based cluster keeping method suitable for implementation in long-term cluster flight missions consisting of multiple satellites. The control law uses the Brouwer-Lyddane differential mean elements as feedback. This algorithm has been implemented on the nanosatellites planned to be launch as part of the Space Autonomous Mission for Swarming and Geo-locating Nanosatellites (SAMSON). A nonlinear DD-based controller for matching the secular components of the semimajor axis and the argument of latitude is developed, and its stability is proven using finite-time stability theory. High-precision simulation results confirm that the new controller is able to arrest satellite relative drift for mission lifetimes exceeding a year, and, on the other hand, provide collision-free operation.

Obviously, any drag-based algorithm must cope with aerodynamical and mechanical uncertainties. The overall error related to drag calculation is inevitable and could be as high as one or two orders of magnitude, which can be crucial for any drag-based control. Hence, a covariance analysis of the closed-loop system was developed, in the presence of drag uncertainties, initial condition-related uncertainties and measurement noise. A Kalman filter is designed in order to generate inputs to the differential drag controller. The variances of the differential mean semimajor axis and the relative distance are propagated analytically using the Linear Covariance Analysis (LCA) technique, which enables to propagate the augmented state and filter covariance without propagating the state itself. The analytical results are validated by a Monte-Carlo simulation, which shows that drag uncertainties have small effect on the inter-satellite distances.